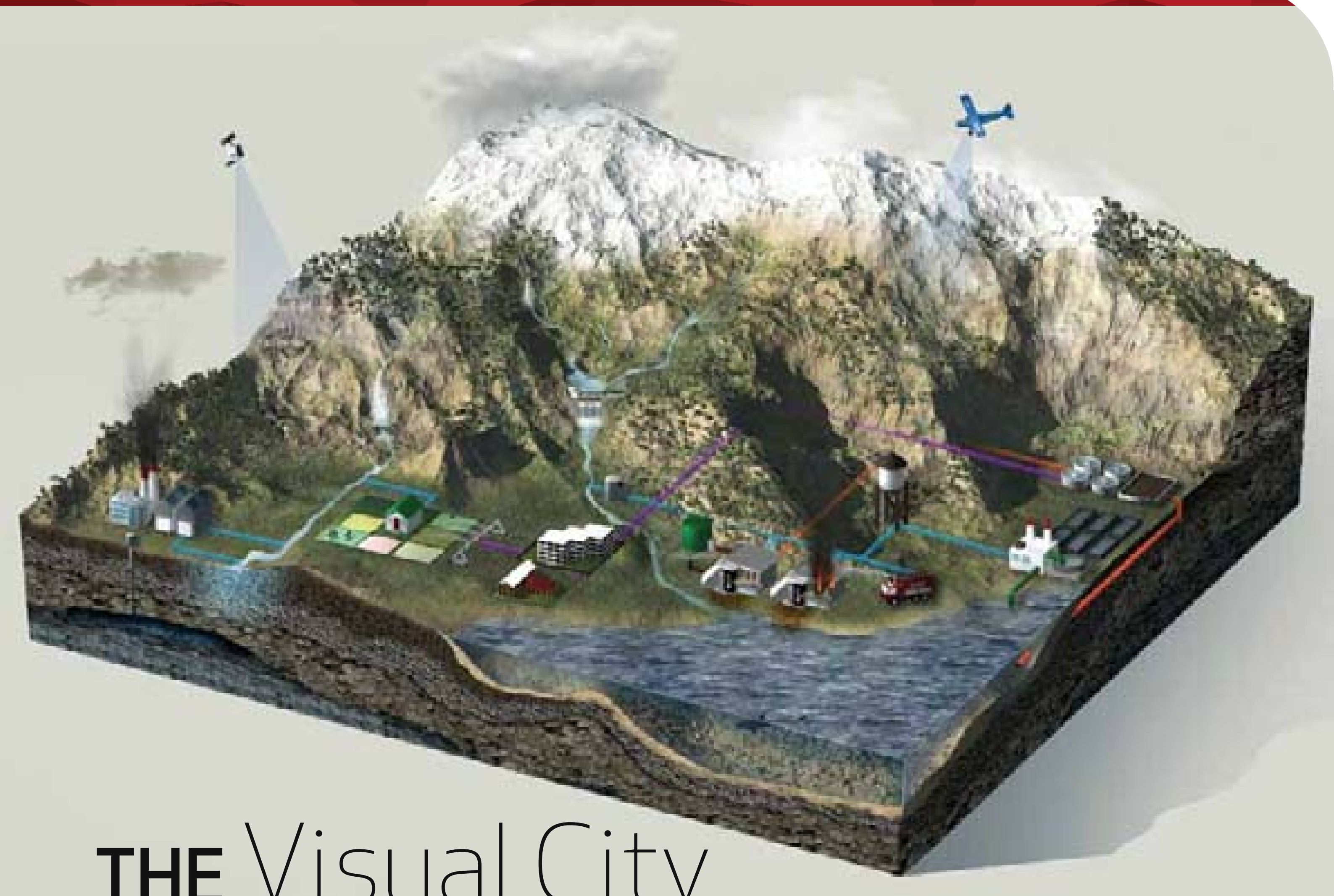


THE Visual City

...to present the known world as one and continuous, to describe its nature and position...

Geographike Uphegesis, Ptolemy c.AD 120

March 2011

'us' Utility Services

nextspace™

Contents

Water in the City

The challenge of growing population and business investment will place greater demands on city infrastructure. The focus of growth and transformation of cities will be around re-envisioning the built environment and delivering associated infrastructure systems to meet the high expectation of level of services in cities for wealth generated. In the case of water infrastructure, all this must be delivered within the constraints of a resource increasingly under pressure.

While public sector budgets are being squeezed, these challenges faced by cities are not going away. Globally, water authorities are increasingly being more creative and more efficient in their use of public funds and private investment – doing and achieving more with less.

The issues of urban water are complex, intersecting across physical, spatial, temporal dimensions.

Recent shifts in integrated water and catchment management provide a context for resolving some of this complexity. The shift highlights the future for water in our growing cities will involve significant departures from conventional urban water management approaches to a sustainable communities approach. These approaches are characterised by lower water consumption, preservation of natural drainage, reduced generation of wastewater through water reuse and recycling, advanced water pollution control, and preservation and/or enhancement of the receiving water ecosystem.

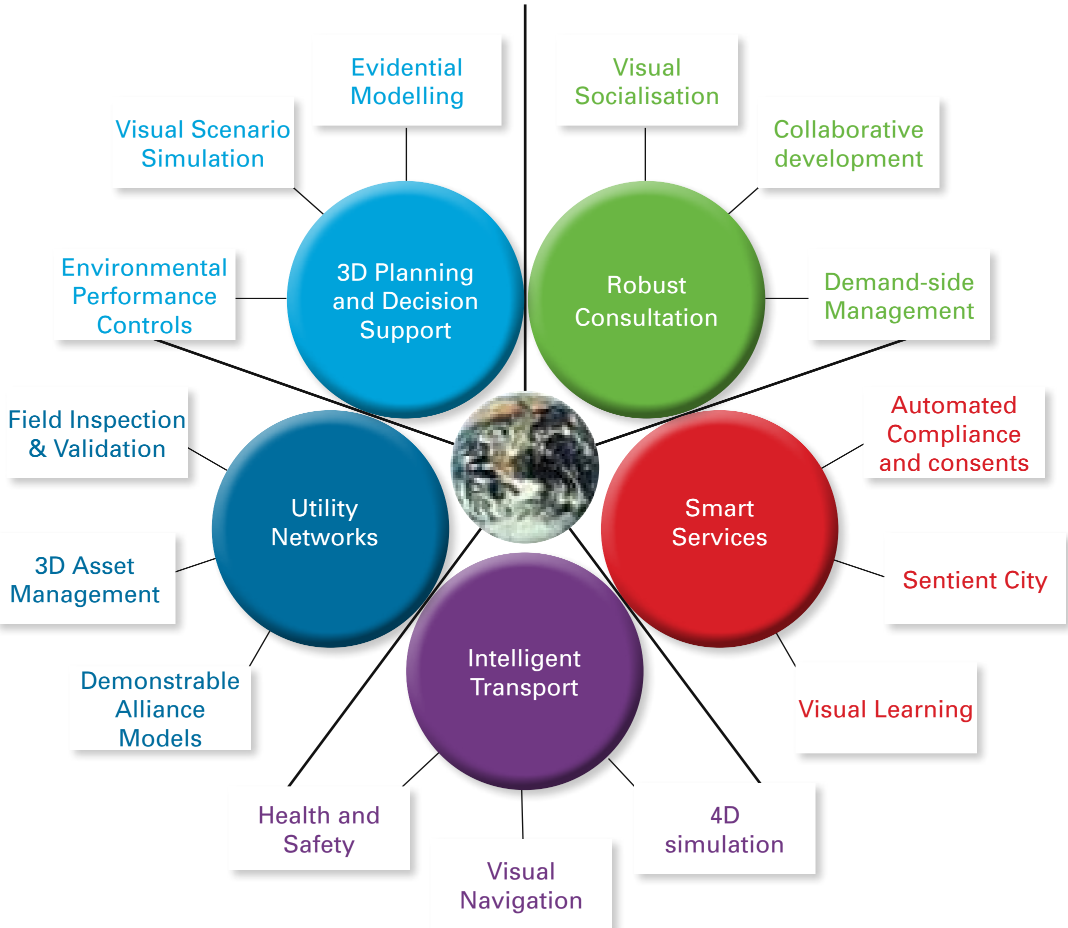
The shift for water management highlights that water cannot be treated in isolation or at the end of urban design and development – it must be fully integrated across all (supply, waste, storm) waters and urban design (buildings, transport, communications), be adaptive and resilient.

The Visual City provides a platform for realising these opportunities and accelerating this shift.

The Visual City

The Visual City platform is the new physical-digital landscape now emerging, linking places and spaces to the unparalleled amounts of multi-dimensional information available today. The Visual City can capture, store, process and display multi-dimensional information about cities – like maps, plans, resource consents, operational systems such as GIS, aerial imaging, LIDAR, live sensor feeds, RFID, building models and transport routes – and a wide variety of economic, social, environmental and cultural phenomena – such as historical records and photographs.

The Visual City platform catalogues and codes data to geospatially referenced points in ways that enable it to be linked, referenced and cross referenced. The data can be seamlessly accessed by multiple users and applications, subject to the same security access controls and privacy rights available in the real world. Information collected at one level can be shared between all the different levels, detailed for comprehensive investigations, general for strategic purposes – and as new data or changes in existing data in the platform automatically update applications. Data can be combined in multiple ways to develop unique and robust applications across the city.



3D Visualisation is key

The challenge to make all the geospatially referenced data easy to understand and interpret is managed by visualisation within the appropriate context selected in a user-friendly way.

Visualisation is key, visualisation of the natural and the built worlds, the real and the imagined worlds. 3D visualisation technology transforms the integrated data and information from flat, static imagery into dynamic, quality, content-rich applications for city services, systems and community engagement.

When the model changes through information change or new inputs, visualisations can be automatically updated and rendering triggered. The visualisations are therefore not just explicit expressions, but intrinsically tied into the dynamics of the City. This approach means faster deployment of evidential information into the decision making processes. Over 80% of decision making in government includes geographic information[1]. With information more accessible and usable, there are more opportunities for innovation.

Water in the Visual City

Water in the Visual City makes possible a new generation of solutions that respond to the challenges of growing cities and ways water impacts environmental, social and economic well-beings. It establishes a platform to translate existing urban water management to a new increasingly sustainable framework[2].

	Current framework	Future framework
System Boundary	Water supply, sewerage and flood control for economic and population growth and public health protection	Multiple purposes for water considered over long-term timeframes including waterway health and other sectorial needs i.e. transport, recreation/ amenity, micro-climate, energy, food production etc.
Management Approach	Compartmentalisation and optimisation of single components of the water cycle	Adaptive, integrated, sustainable management of the total water cycle (including land-use) designed to secure a higher level of resilience to future uncertainties in climate, water services requirements while enhancing the livability of urban environments.
Expertise	Narrow technical and economic focused disciplines	Interdisciplinary, multi-stakeholder learning across social, technical, economic, design, ecological spheres, etc.
Service delivery	Centralised, linear and predominantly technologically and economically based	Diverse, flexible solutions at multiple scales via a suite of approaches (technical, social, economic, ecological, etc.)
Role of public	Water managed by government on behalf of communities	Co-management of water between government, business and communities
Risk	Risk regulated and controlled by government	Risk shared and diversified via private and public instruments
Collaborative	Limited influence on decisions that affect the shape and density of cities.	Collaborative planning to deliver a shared vision bringing together water, transport, health, employment, social services and other sectors

Water in the Visual City makes possible a new generation of solutions.

Water: the global resource

Global water system.

These circles show just how little of the world's total water supply (A) is fresh water (B) and little of that amount is actually usable fresh water (C).

Of this amount only 5% of C is used.

New Zealand uses the 5% of water[3] for:

- **77% for irrigation**
- **3% for stock watering**
- **9% for public water supply**
- **11% for industrial**

A
World's total water supply: 1386 million km^3, 97.5% is salt water

B
This block represents the 2.5% that is freshwater but almost all of this is in ice or underground

C
This drop represents the tiny amount (0.01%) that is not in ice or underground

The remaining 95% flows to the sea or underground aquifers maintaining ecological health, instream cultural and recreational needs, and minor human, stock and firefighting needs[19].

The daily drinking water requirement per person is 2-4 litres, but it takes 2 000 to 5 000 litres of water to produce one person's daily food.

Freshwater is:

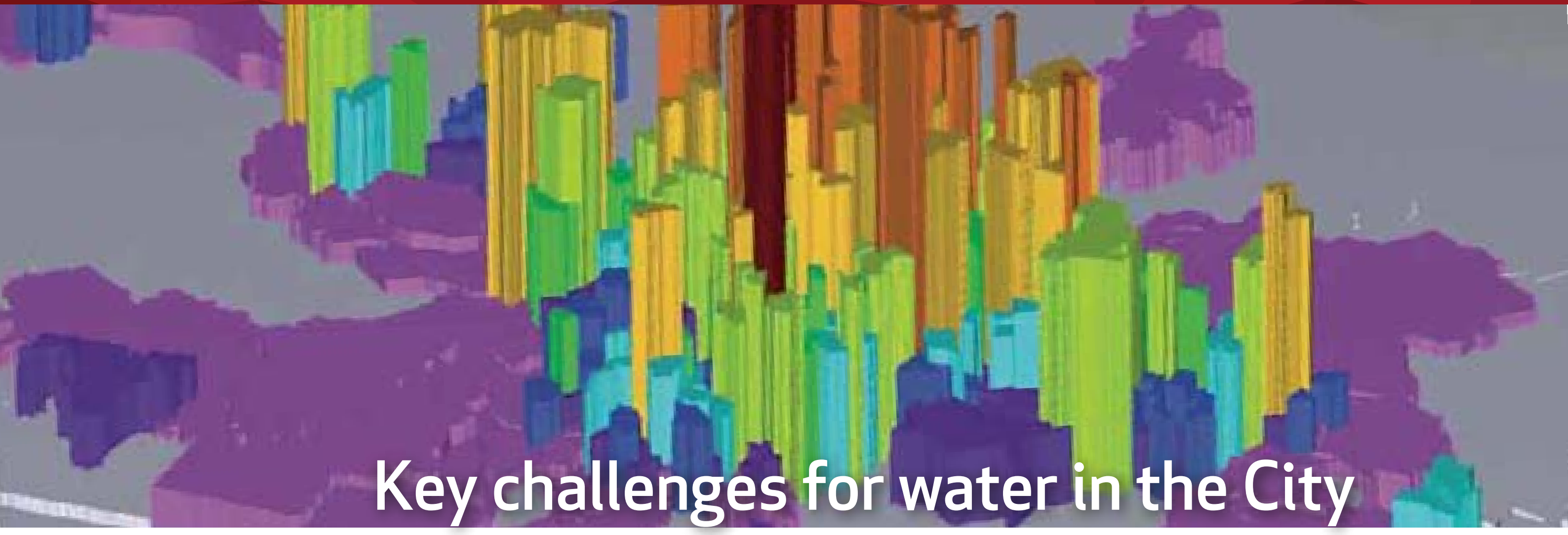
- An essential resource for agriculture particularly irrigation and livestock.
- Used by industry – the second largest use of water.

The largest single use of water by industry is for cooling in thermal power generation. Power and industrial companies use significant amounts of water in production processes and as a coolant – 16% of global demand, rising to 22% by 2030. Moving water at these volumes and using it in some processes (eg steel, power) requires a great deal of energy, so using less water to do more also means using less energy.

- A major energy source.
- A major part of healthy ecosystems.
- Has significant cultural, aesthetic and spiritual values to our communities. For others, it is the opportunity it provides for leisure, recreation and sport.
- Used by some businesses to assimilate wastes.

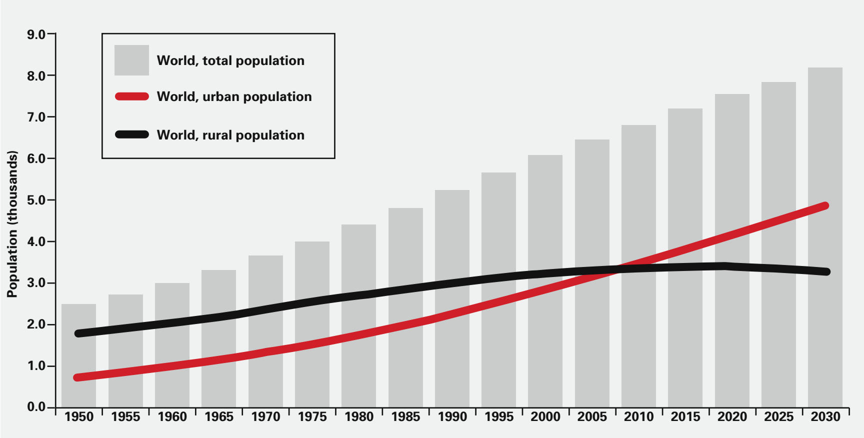
Waste and contaminants enter water at controlled point sources (like pipe outfalls) and surface runoff and leaching through the ground. Runoff and leaching are harder to control, so limits can be exceeded and water quality declines.

Countries with targets for renewable source generation rely on hydropower to generate renewable electricity. This water remains in the waterway and is available for other users.



Key challenges for water in the City

The urban and rural population of the world, 1950-2030



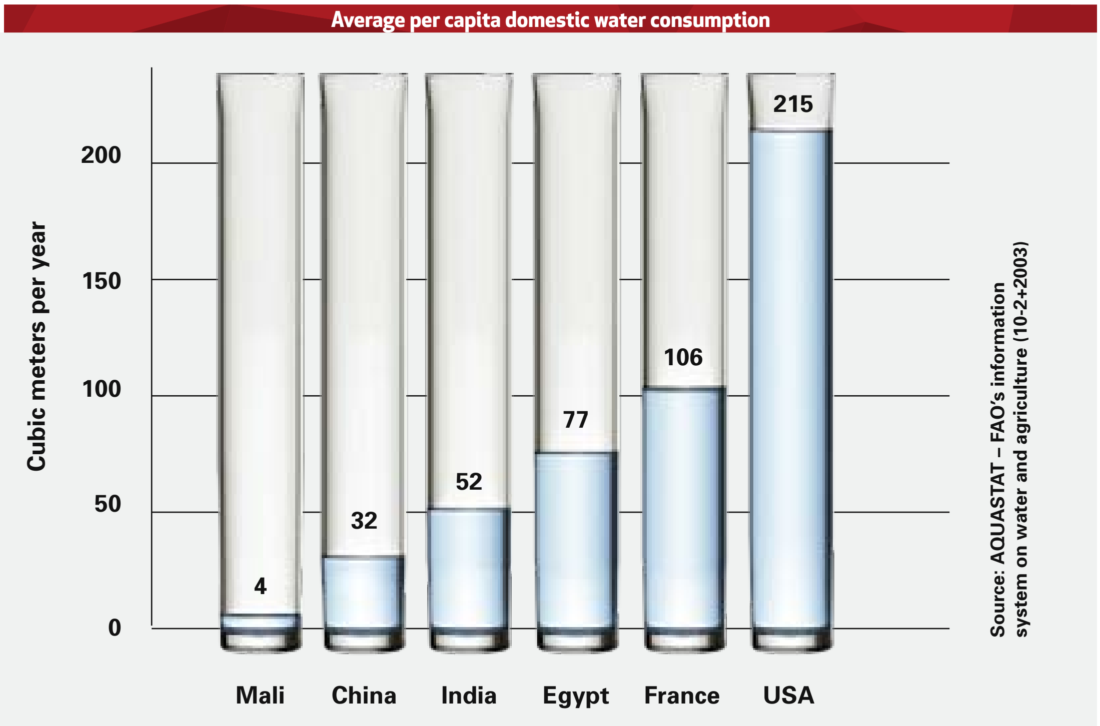
Increasing urbanisation

Today the world population is 6.5 billion; in 2050 it is estimated to be 9 billion (with 8 billion in developing countries).

The rate of urbanisation is unparalleled in our history, 50% world's people currently live in cities. An extra 60 million new town and city dwellers arrive every year, and by 2050, 70% of the world's population will live in cities. Today, over 450 cities already have in excess of 1 million people.

Challenges for the water sector:

- Water use has been growing at more than the rate twice of population increase in the last century.
- In 60 percent of European cities with more than 100,000 people, groundwater is being used at a faster rate than it can be replenished[4].
- Over the next 20 years, humans will use 40% more water than they do now.
- Significant investment in water infrastructure is necessary to deliver water to individuals and business and to process wastewater from these users, in order to protect citizens and biodiversity from diseases and the environment from harmful impacts.
- Understanding the importance of identifying and investing in the social, cultural and recreational values of water.



By 2050 the world's water will have to support the agricultural systems that will feed and create livelihoods for an additional 2.7 billion people[5].

A wide variation in average per capita domestic consumption is observed across different nations.

The UN suggests that each person needs 20-50 litres of safe freshwater a day to ensure their basic needs for drinking, cooking and cleaning – this amounts to around ten cubic meter per year.

Centers of global economy

For governments and business, the opportunity is that this population growth will deliver in the specific locations – global cities – billions of new consumers. The increasing affluence of these city based consumers means increased demand for water and the services it provides.

Challenges to water sector:

- A diversified economic base, including higher specialisation in productive activities, increased trade in agricultural and industrial products, globalisation of investments and financial markets, privatisation of water systems, and advances in communication, information and biotechnology are also beginning to alter the patterns of supply and demand for water and are putting increasing pressure on water resources and natural ecosystems.
- No society, community or business can operate without water. There is a need to be able to 'future proof' water supply for increasing populations even in existing water stressed, high-demand catchments.
- A common visual language of progression that all stakeholders can engage with to understand and communicate complex spatial issues and policy.

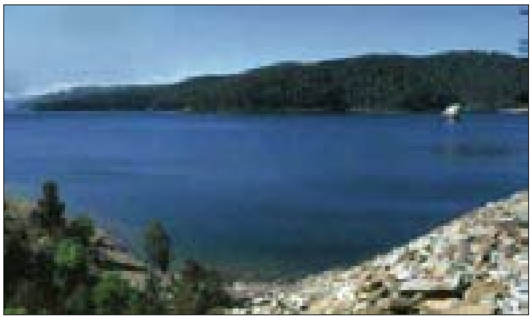
In Canterbury, New Zealand, between 1999 - 2006 the land irrigated for agriculture has increased over 50% (from 400,000 ha to 630,000ha)[6] and as a consequence, in some areas 'red zones' have been activated and restrictions on further abstractions from ground water resources are in place.

Melbourne and surrounding areas have been in drought since 1997. From over 90% in 1997 storage levels have dropped to slightly over 30% in 2010.

Climate Change

Climate change poses a series of risks to water availability and water management systems, although much uncertainty remains. Climate change could increase annual precipitation and make more freshwater available in some places. Where rainfall patterns decline and inflows reduce to stored reserves, it becomes increasingly difficult to maintain supply during these drought conditions. The South Eastern Australian Climate Initiative found the decline in rainfall in Australia was due to rising levels of greenhouse gas emissions rather than natural variability.

Around 18 of the 23 mega cities worldwide located on a river delta or on the coast have an increased risk of flooding and damage as a result of storm events and potential sea level change need to be managed.



Thompson Dam 1997

Thompson Dam 2009

Auckland recorded 2500 incidents of wet weather overflows in 2008, mostly as a result of an ageing combined stormwater and sewerage network. Problems arise when rain overloads the network, flushing contaminated water into the sea. While investment and progress is being made, Auckland still has 200 km of combined stormwater and sewerage pipes.[7]

Challenges to the water sector:

- Adaptability, security and resilience are essential to mitigate climatic variability – water scarcity in drought conditions can be replaced by widespread and devastating water surplus as high intensity rainfalls can generate torrential run-off and rapid rises in stream discharge in just a few hours.
- It is essential to develop future proofed urban water systems to mitigate the likely impacts of climate change including:
  - potential for corrosion and odours caused in sewerage network arising from increased sewerage concentrations
  - risk of pipe failure and collapse due to dry soil conditions
  - the increased infiltration of seawater into sewerage and wastewater systems leading to rising salinity levels in recycled water
  - risk of damage to infrastructure (viz underground drains, levee banks, pump stations) resulting from higher peak flows due to more frequent extreme weather events

Environmental and ecosystem damage

Cities with a diversified economic base, including higher specialisation in productive activities require increased water supply and sanitation services, creating more pressure on water resources and natural ecosystems.

In some locations, increases in water use incur high environmental costs, including loss of biodiversity as well as affecting natural water systems such as rivers and aquifers. Environmental flows are further stressed by long periods of low flows and dry conditions.

Half of the world's wetlands have disappeared over the last century, with some rivers now no longer reaching the sea, and over 20% of the estimated 10,000 freshwater fish species are now endangered or extinct[8].

Other threats to the environment impact water systems. Water systems need to be able to provide sufficient water at pressure for firefighting. Where fire damages catchments supplying urban water, cities must respond immediately to manage the impact on the quality of water supplies, including the prospect of decreased water yields from catchments as forest regenerates.

Hat Yai, Thailand, a city located above a productive aquifer, has major contamination problems of its water supply due to unregulated groundwater exploitation and the disposal of solid and liquid wastes above or into the aquifer[8].

Challenges to the water sector

- Current water management is clearly not working to support high quality environmental outcomes in the face of escalating demands for water.
- In many areas of the world, drinking and wastewater infrastructure is aging. The costs and environmental risks due to failure are significant.

In the US every year some 240,000 drinking water mains break costing billions in lost water; wastewater collection systems experience some 75,000 sewer overflows, discharging 3-10 billion gallons of untreated wastewater into the environment[9].

How the sector is currently responding

The challenges of balancing the needs of urbanisation and economic growth together with providing community benefit and sustaining environmental wellbeing is continuing to push the traditional boundaries of management of the urban water cycle.

While cities around the world face different challenges to deliver this balance, existing technologies and innovative solutions are beginning to respond to urban water challenges.

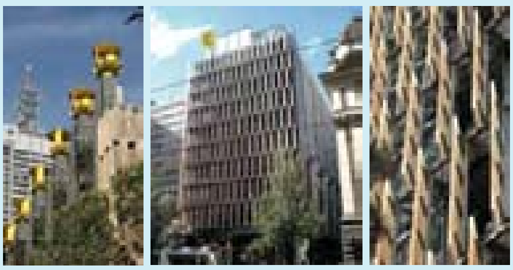
Best practice solutions supported by integrated, multi-stakeholder approaches are increasing the capacity of the sector to:

- achieve greater efficiency in operations which is increasingly being secured as water infrastructure is more strongly linked with urban design.

In Melbourne, Australia, over 65,000 million litres of recycled water were supplied in the metropolitan area for irrigation of open spaces and industrial processes[10]. This growth in recycled water applications is supported by the Government's potable substitution targets.

- secure new approaches to finance are critical not only for new and replacement infrastructure, but to maintain water infrastructure at the current service level and to comply with stricter standards.

OECD nations need to invest at least US$ 200 billion per year to replace aging water infrastructure to guarantee supply, reduce leakage rates and protect the environment water quality[11]. In Australia, annual maintenance costs for aging water infrastructure are over A$4.5 billion. In the US, it is estimated that annual investments of US$ 23 billion will be needed over the next 20 years[11]. Given the significant investment, the water sector continues to develop investment evaluation and pricing models that capture total costs, while at the same time provide affordable services to the community[12].



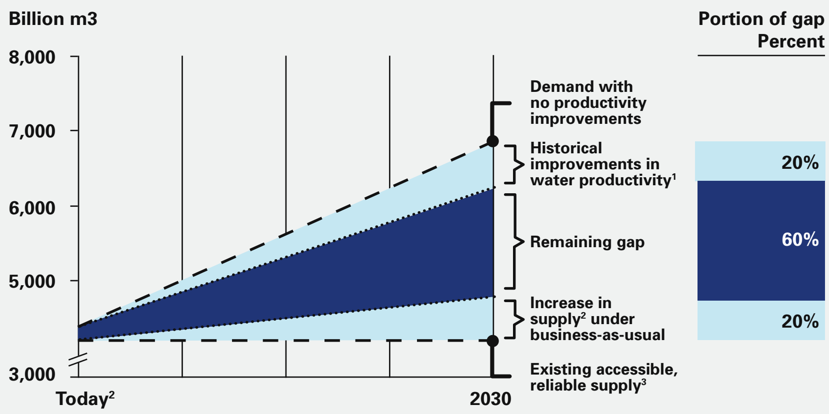
The City of Melbourne's Council House 2

Australia's first Green Building Council 6 star rated commercial building was designed to reduce mains water consumption by more than half an equivalent building. Water efficient fixtures and on site rainwater collection, blackwater and greywater treatment on site provides 72% of non-potable water.

- invest in new and existing technologies that drive high performance. As business models change, municipal water utilities are moving to develop cost-effective water supply and wastewater options for domestic and business use that will reduce water consumption per dollar of output and work towards the goal of zero discharge. Low impact urban design and decentralised approaches provide some of these solutions. These solutions are securing productivity improvements and continually work to close the demand gap for raw water and costs associated with high waste water volumes.

- strategically work to deliver future water opportunities and options. Integrated catchment management (ICM) is being used since it provides opportunities for sustainable outcomes across multiple sectors taking into consideration: public interest values, stock and firefighting needs, the ecosystem, municipal 3 waters – supply, waste and stormwater – cultural, recreational, agricultural and other industrial uses and power generation. ICM reflects that the uses of water are not isolated from each other, many uses contest for the same water or impact other uses.

Business-as-usual approaches will not meet demand for raw water



1 Based on historical agricultural yield growth rates from 1990-2004 from FAOSTAT, agricultural and industrial efficiency improvements from IFPRI

2 Total increased capture of raw water through infrastructure build out, excluding unsustainable extraction

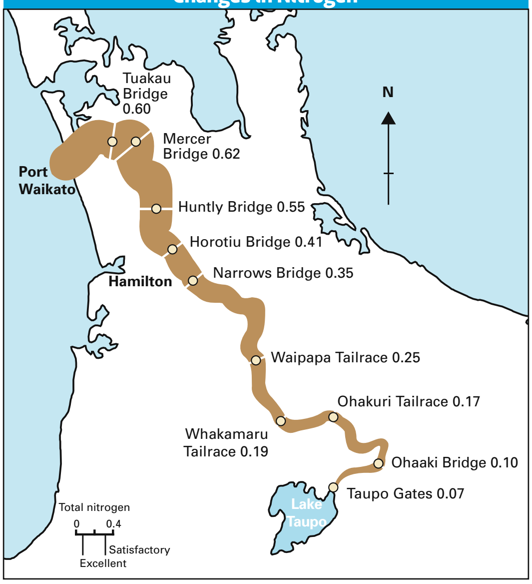
3 Supply shown at 90% reliability and includes infrastructure investments scheduled and funded through 2010. Current 90%-reliable supply does not meet average demand

SOURCE: 2030 Water Resources Group – Global Water Supply and Demand model; IFPRI; FAOSTAT

Source: Charting our water future – McKinsey 2009

CASE STUDY: *CHANGES TO WATER QUALITY IN A CATCHMENT IMPACT DOWNSTREAM MUNICIPAL SUPPLY*[13].

Changes in Nitrogen



Auckland, New Zealand, takes part of its water supply from the Waikato River around the Tuakau Bridge (as marked). Total nitrogen levels above 0.5 grams per cubic metre are undesirably nutrient-enriched. The quality of the water at this extraction point means additional costs in membrane filter technology to treat the water to potable standards.

Predicted dairy conversions (a land area the size of Lake Taupo) are expected to increase the Waikato catchment's nitrogen load by 70% by 2030.

The implications for municipal water treatment costs are significant, and will impact smaller urban centers taking water from the Waikato, who can ill afford costs associated with high level membrane technology.

2,700 litres to make a shirt. Of this 45% is irrigation water; 41% is rainwater that fell on the cotton field during the growing period; and 14% is water required to dilute the wastewater resulting from fertiliser use in the field and chemicals in the textile industry[14].

- user education and best practice through conservation of use and shifting expectations to 'fit for use' supply of water within a property.

Most consumers are unaware of the significant volumes of water required to produce everyday consumer goods, the wastewater required to be treated, and the impacts of production and energy requirements on our water resources.

Are we moving fast enough?

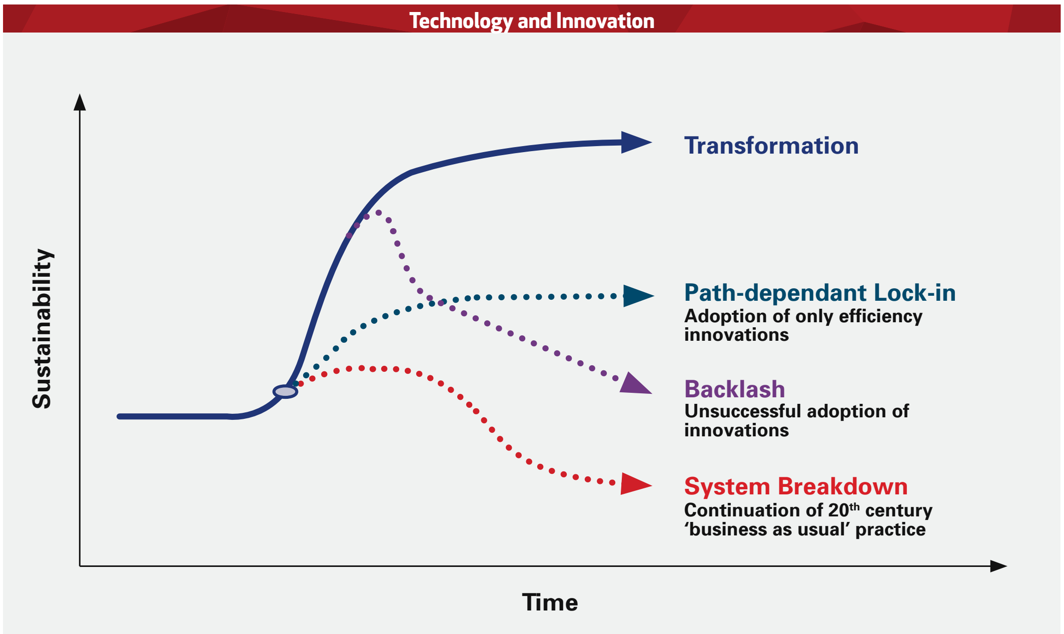
The sector continues to evolve and develop in response to the challenges faced. Water utility sector research and current operation outcomes suggest, however, the pace of change associated with 'business as usual' is unlikely to be able to quickly resolve the complex and costly challenges faced by urban water utilities.

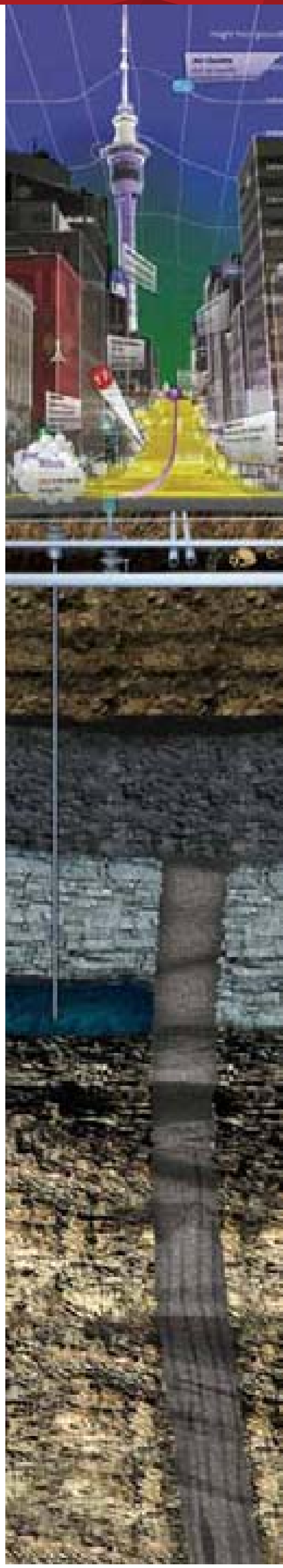
The urbanisation process has only just begun... we're therefore going to need completely ***new infrastructure concepts*** that address the requirements of both a growing urban population and environmental protection[15].

Building tomorrow's water systems today

Visualisation is currently part of the water sector. Existing systems map and contour ground water levels and contaminant distributions from remote sensor webs. This enables decision making regarding remediation of salinity or contamination, management of aquifer recharge, together with the interactions between ground water and surface water to be better understood. Hydrological catchment models are widely available.

Blending these discrete systems into a comprehensive platform and making them available to inform other applications and decision making events is now possible. The tools to accelerate the transformation of the water sector are here – now.





A new generation of solutions

CASE STUDY: *BELGRAVE HEIGHTS PRESSURE SEWER SYSTEM (PSS), SOUTH EAST WATER LTD*

Construction Benefits

In cooperation with the Capital Delivery team for ‘us’ – Utility Services (South East Water’s Operations, Maintenance and Capital Delivery Program Alliance), the Belgrave Heights PSS project was selected for the pilot program. This particular project provided the potential to explore the potential cost and communication benefits for ‘construction’ as well as ‘engagement’ with South East Water’s end user customers.

During the planning stages, models were built and 3D visualisation technology was then used to identify the location of critical rock formations in Belgrave Heights. Drawing in geological survey data from a number of sources, the system was able to show the project team underground land form that has previously not been available in a visual format. Teams planning for pipeline alignments and the position of infrastructure, including grinder tanks for individual properties, were able to draw on this additional information. Rock formations in the local area were of particular concern and the added capacity to visualise their location assisted with design – finding alternative and more cost-effective pipeline alignments.

During the pilot, 3D visualisation supported the South East Water project team to make decisions and minimise risks, modelling potential cost savings and demonstrating the potential for future construction program value.

Customer Engagement Benefits

Throughout the construction phase of the Belgrave Heights PSS project, South East Water has worked to reduce its impact on the local community and the environment. The successful delivery of any PSS project is reliant on maximising the number of end user customers who connect to the system. By integrating 3D visualisation technology into South East Water’s customer and community engagement program, value at the residential property level can be demonstrated. The customer connection process includes consultations, site audits, surveys, construction and commissioning elements that each take time to implement for each residential property. The development and use of visualisation technology means timeframes at each step of the connection process are reduced, resulting in increased efficiencies and lower costs. Each process improvement, supported by system developments, can potentially have a positive impact on customer satisfaction.

3D visualisation means consultations could take place off-site (for example, at the client’s work place). Residents and project team members will be able to take a tour of properties and construction zones in 3D, adding details to the system and locations for a variety of assets. Interfacing applications will allow for diagrams and plans to be viewed and edited in the field, improving the accuracy and availability of South East Water’s information. Reduced administration and certification times with third party auditors, surveyors and South East Water having access to shared property information, synchronised in ‘real time’.

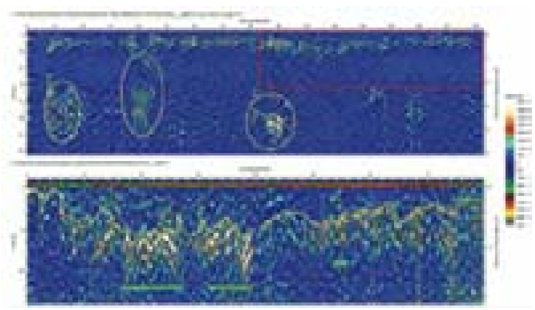
Demonstrated Value from Visualisation

To try and put a value on the potential for reducing construction costs, South East Water estimates that the difference between installing PSS 'grinder units' in rock when compared with softer ground. By utilising visualisation technology to find alternative locations for each high risk unit, project teams estimate significant savings in both construction time and cost of materials and resources. These planning calculations highlight the potential for visualisation technology to provide the project with more of the information needed to make the most informed, cost-effective planning decision possible.

South East Water expects to demonstrate construction cost value in terms of planning and infrastructure placement. It has also been able to recognise the potential for further system developments that will provide customers with more detailed and powerful information, using state-of-the-art communication tools.

System mobility is a key success factor and with the relatively recent release of the Apple iPad (and similar devices) in Australia, this device enables a portable and interactive tool for customer interface applications. Each of these platforms will dramatically improve our mobile communication systems to support the base visualisation technology.

There are potential benefits for end user customers throughout the process with reduced times for 'sign-off' at each stage and reduced construction costs for customers and South East Water. For every potential improvement in time and cost, there is a direct impact on customer satisfaction which ultimately influences the number of customers connecting to the system.



Ground Penetrating Radar (GPR) can be ingested into the Visual City to further inform the evidential model of sub-surface rock that is evolved from geomorphology and borehole data.

Make-up of the Current System and Future Developments

At the systems core is the Visual City platform which gathers and amalgamates information from a variety of sources. The forms of data available for integration include:

- Asset Information – water and sewer network assets
- LIDAR (Light Detection and Ranging) Surface Data
- Property Information – property polygons and addresses
- High Resolution Aerial Photos – accurate to 10cm
- Sub-surface Terrain Data – sourced from geological surveys
- Geomorphology Studies – based on local erosion, terrain and aspect information
- Proposed Pipeline Design – proposed alignment of assets with respect to sub-surface terrain
- Feature Survey Information - location of above ground features and obstacles
- Other Utility Assets – above and below ground

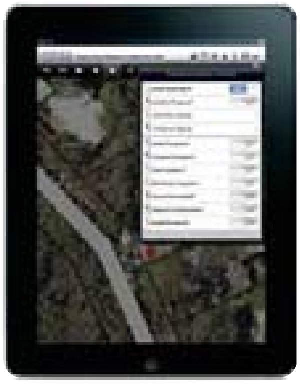
In further development is a variety of interfacing tools that can effectively integrate and display desired information and produce a better understanding of:

- Sub surface construction zone – from surface to a depth of 2.0 metres
- Areas where the top soil is deep – low risk of obstruction
- Areas with high likelihood of large boulders below the surface and within the construction zone – medium risk of obstruction
- Areas with high likelihood of solid rock at the surface – high risk of obstruction
- Trees and other above ground immovable obstacles
- Property Aesthetics – how the low pressure sewer system work will look in its landscape

"There are clear benefits in being able to communicate visually with our customers and our operators, we see that at Belgrave, and we will get continued benefit from the customer design tools."

Rohan Ogier, TOC Development Manager, 'us' – Utility Services.

3D example of rock and sub-soil at selected property



Property workflow inspection

Placement of grinder tank

South East Water will be able, in Belgrave Heights, to adjust pipeline alignments and the proposed location of infrastructure to accommodate the local, natural environment. Once pipeline alignments within the construction zones have been identified, a series of final tests in high risk areas will be undertaken to confirm the planning data and terrain conditions prior to work commencing. This confirmation data feeds back into the system and enhance accuracy in specific areas over time and is available for future projects. The range of confirmation surveys and tests include:

- Geotechnical surveys – soil samples to determine depth and density of rock
- Ground penetrating radar – to identify depth of solid rock or possible sub surface boulders
- Vegetation – to avoid damage to root systems
- Areas of cultural significance – possible location of archaelogical sites
- Location of contaminated ground – retired land fill sites pose a high risk for OH&S

Combining this additional information using one system that is then capable of producing 3D visualisations for a variety of purposes, will reduce construction costs, improve OH&S, better protect the environment and reduce the use of loud construction equipment – all of which has a positive impact on the community and environment.

Using 'real' property examples, South East Water is now able to finalise development and field test applications using mobile devices such as the Apple iPad. South East Water staff and its independent audit contractors will be able use mobile and 3D applications for the following activities:

- Plumbing compliance checks for each property
- Electrical checks and testing for each property
- Generate design drawings
- Customer consent and connection agreements
- Track installation progress

By enabling its staff and contractors to access and update information at each property (approximately 800 in Belgrave Heights) South East Water will be able to reduce timeframes for each network connection.

Conclusion

Together, we are seeing the development of a technology approach that will take us forward and solve business problems in an innovative and visual way, not previously explored within the Water Industry. In doing so, we hope to enhance understanding and therefore clarity between all parties, decreasing the gap between what parties 'know'. We hope to develop a flexible and scalable technology platform that will meet the demands and challenges we will face over the next 20 years, with the application of powerful 3D information and visualisation.

The case study in Belgrade Heights demonstrates the power of the Visual City platform in integrating multiple data sources and known solutions to inform an entire service or system, community and stakeholders, using visualisation. Visualisation is driving innovation enabling collaboration and curation. Visualisation is letting us see things and relationships we can't actually see.

Multiple data sources: Multiple opportunities

The Belgrave Heights project clearly demonstrates the capability of the Visual City platform to catalogues and codes data to geospatially referenced points in ways that enable it to be linked, referenced and cross referenced for water decision making and appllcations. Information collected at one level is shared seamlessly between all the different levels in a form appropriate for the application. Both existing and new applications can be enriched through visualisation of the combined, spatially referenced data.

	Geo/systems	Legislative/regulatory	Technical	Other
Global	Global Navigation Satellite Networks (GPS,GLONASS, Galileo) Laser and radar altimeters IKONOS LANDSAT SPOT		Digital Earth GEOSS	Copenhagen Accord United Nations Framework Convention on Climate Change UN Metropolis
National	GIS/LIS/SDI Soil Moisture and Ocean Salinity (SMOS) Quickbird	Resource management	Water efficiency targets	Energy targets
Regional	Catchment geomorphology; hydraulic Hyperspectral Aerial imagery Digital elevation (terrain) Synthetic Aperture Radar (SAR) Seismograph Light detection and ranging (LIDAR)	Regional plans and policies Integrated catchment management Demand management policies;	Works management programmes (TOC and other strategic reporting)	Utility data – gas, electric, telecom Asset data, roads, footpaths ERP Document management
Local	3D Laser Survey Monitoring use/ discharge Ground penetrating radar Building Information Model (BIM) Borehole seismography Borehole data	Codes of subdivision and development; land use constraints	Networks, plan, design, build Asset management Crowd Sourcing Sensor Web telemetry cctv logging Geotech (bore holes, manhole covers)	Blogging as in fix my street Photographs Customer survey Opinion mapping Consent dialogue Social Networks
Property	asset verification property survey drainage connections consultation piping and plumbing			rainwater harvesting and garden management building performance rates and user charges property inspection

The deluge and representation of data and information specific to water.

Update frequency of data

- real time (purple)
- daily-weekly (red)
- less than 1 year (blue)
- 1-5 years (green)

Further applications of Water in the Visual City

City data, much of it unstructured, and unqualified is often yielded unavailable by administrative siloing (as demonstrated in the previous table). With the growing uptake of real-time sensor webs, and sweeping of cities with ever increasing resolution of aerial sensor technologies, the frequency of our updated information has increased significantly. The increasing ubiquity of smart devices is transforming people into real-time 'sensors', and augmented reality is enabling coal-face validation of data. Sensor-webs are providing live feeds, and with RFID these physical-digital ecology becomes a sentient world.

The Urban Environment

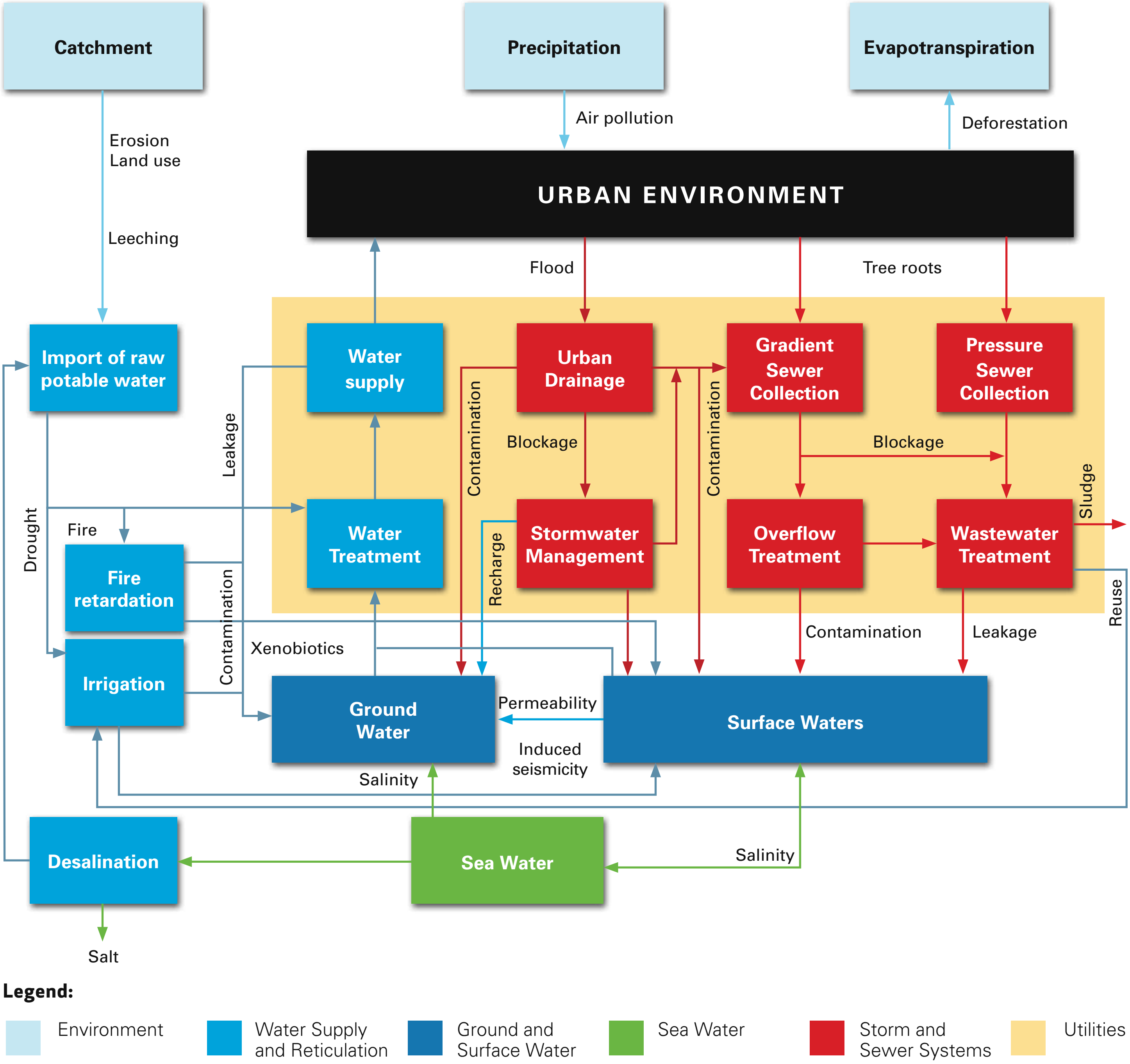
The challenge is to manage these vast city datasets, their multiple formats, and states of confidence in a manner where data can be fused and derived into useful and informative outputs for the urban water environment. Meeting these challenges of data streaming are new, proven visualisation tools that graze vast data sets and innovative evidential delivery infrastructure for management.

These tools seek to allow us to rapidly respond to the real world situations, enable greater evidence driven decision making, automatic generation of data derivatives, facilitate more informed and collaborative consultation, and process transparency.

The Visual City platform has successfully been demonstrated to accelerate these transformations in the water sector so that the sector can meet the range of urban challenges it faces. The Belgrave Heights case study demonstrates how drawing the rich ecology of data available, the Visual City platform has the delivered efficiencies, productivity gains and innovation across the company.

The platform has the promise of further transformation of existing operational, decision making, consultation, design and planning of water services and infrastructure. Opportunities to extend the platform to realise benefits across other water operations and services, integrating multiple services and city infrastructure, together with wider impacts of water management can be clearly identified.

Further developments in the urban water cycle and key issues[16]



The SMOS satellite with radiometer 'blades' for measuring Soil Moisture and Ocean Salinity (SMOS). This mission has been designed to observe soil moisture over the Earth's landmasses and salinity over the oceans. Soil moisture data are urgently required for hydrological studies and data on ocean salinity are vital for improving our understanding of ocean circulation patterns.

Environment

In the past, information about the environment was assembled from on-site observations and sensors. Given the complex dynamics and the limited scale of the sampling it would never be comprehensive enough to provide a real-time, real-world snapshot of the environmental status. This is rapidly changing with an increasing number of ways in which vast amounts of data can be sensed and captured as information, as imagery, multi-dimensional models and visualisations.

Climate variation and extreme weather management

Heavy precipitation causes the saturation of the soil and this increases surface flow and risk of flooding. During the Queensland floods in 2011, the first rains drenched/saturated the top soils so that the subsequent rain event led to exceptional flooding. Satellite and aerial remote sensing the Australian rain deluge and increasingly soggy ground at the height of the natural disaster has been documented by the European Space Agency SMOS satellite (launched in 2009). This data linked with sensor webs in for environmental monitoring in urban and natural environments provides opportunities for new, more responsive extreme event impact monitoring, and potentially can be used in urban search and rescue and infrastructure protection during extreme events.

Environmental well-being monitoring

Urban areas differ significantly from natural environments. Large parts of a city are impervious – covered by concrete or asphalt roads, pavements and rooftops. This results in reduced infiltration and evapotranspiration due to reduced vegetated areas.

Hyperspectral sensors collect information as a set of 'images'. Each image represents a range of the electromagnetic spectrum and is also known as a spectral band. Hyperspectral data can be used to detect and catalogue trees, determine the chemical composition of plants which together can be used to detect the nutrient and water status. This makes it increasingly feasible for evapotranspiration be predicted, measured and monitored as an index of the actual wellbeing of a city. The automatic detection of surface cover type and impermeability, and chemical state of roofing material on homes helps model runoff for say zinc roofs that can be verified against actual sensor web measures placed along drainage paths and in nearby streams.

Water Supply and Reticulation

Our future prosperity depends upon wise water management. Nowhere on the planet is this more recognised than in Australia - the driest inhabited continent on earth - where climate conditions place enormous challenges on water utilities. Water security given climate change and population growth suggest a long term water deficit that will require cities to prioritise with some urgency significant investment in technologies such as water desalination to meet the predicted demands.

Decentralised solutions – part of a solution framework

The emerging concept[17] of 'Cities as Water Supply Catchments' shifts water access from the singular, traditional potable supply source, to one where water supply occurs through a diversity of sources at a diversity of supply scales. Visualisation of the opportunities to develop comprehensive systems of recycled water, stormwater harvesting and reuse of water at operational, property, area and catchment levels can show how the city will meet water needs with appropriate 'fit for use' supply and inform decision making.

Water infrastructure investment decision making environment when water is an abundant resource[17]

Water available as an undifferentiated commodity → Decision making levels: Government (National, State, Local) Industry Community & individual → 'Least-Cost' investment decisions and water solutions using traditional models and NPV calculations

Water infrastructure investment decision making environment when future water availability is uncertain

Differentiated water entitlements → Decision making levels: Government (National, State, Local) Industry Community & individual → Value-based investment decisions and water solutions incorporating flexibility and resilience both spatially and temporally

Where local solutions provide the required levels of service, there is a trend is to adopt resilient and future proofed decentralised solutions as opposed to large regional facilities. Decisions on which mix of solutions work at in a particular area require the ability to see land use plans that provide direction and ascertain the most suitable water sources in a spatial context. The development of a 'spatial water atlas' mapping network constraints over demand forecasts will assist planning and distribution of property and system level interventions for all supply and demand events.

Personalised know-how specific to each individual property can be shared online with residents as well as with the installers and maintainers.

Onsite installation and monitoring

Irrigation program

Smart meter interface

Telemetry and RFID can be used to provide home-owners live 3D visualisations about their consumption and recommendations for improving sustainable outcomes. Through these tools crowdsourcing can be used to evidentially inform the Visual City.

Asset management

While GIS tools have proven effective in the management of assets, there is often a compromise reinterpreting data associated with the 3D world into the conventions of cartographic 2D. The deluge of data arriving in 3D such as LIDAR, and processing power of smart devices available in the field such as the iPad can now handle the demands of 3D visualisation. There are new challenges that 3D brings, such as demanding of more data and more complete detail. These demands are balanced by benefits such as validating a model against its real world mirror. This can assist in making more informed repair/replace decisions on the maintenance and management of aging water infrastructure.

Non-Revenue Water

Non Revenue Water (NRW) – is water that has been produced and is "lost" before it reaches the customer and can be billed. NRW is a good indicator of the success a Water Utility has had in maintaining its infrastructure, and it is not uncommon for major urban centers to have NRW considerably higher than 15%. High levels of NRW are detrimental to the financial viability of water utilities, as well to the quality of water itself. Best practice operators maintain a very low NRW. Achieving this is critical to ensure affordable and equitable pricing are maintained. Operators such as South East Water achieved one of the lowest NRWs in the water industry through encouraging innovation without compromising social and environmental outcomes. Excellent asset management plays a significant part in keeping this goal, this can be further supported through smart infrastructure and 3D evidential management of full asset cycles.

Emergency services

Emergency systems need to be able to respond to events such as fire with capacity and pressure required can be modelled and tested. Identifying multiple points of possible failure can be predicted through simulation, and through sensor webs and comprehensive management of the asset risks can be mitigated. Responding quickly to contamination of supply from fire areas or storm overflows, monitoring the extent of contamination through sensor webs and then isolating the impact of these events on water supply can be managed leading to cost savings in cleanup and reduction in equipment failure.

Water loss in litres

Leak this size	Loss per day	Loss per month
●	546	16,380
●	1,637	49,110
●	3,150	94,500
●	5,455	163,650
●	8,728	261,840
●	14,074	422,220
●	19,530	585,900
●	30,185	905,550
●	31,749	952,470
●	38,296	1,148,880
●	44,951	1,348,530
●	51,479	1,544,370
●	57,825	1,734,750
●	67,972	2,039,160

1000 litres = 1 cubic metre

Robotic Inspection Tools

A new generation of Inspection tools (Smart Pigs) are able to enhance the reliability of a pipeline and act as an early warning system for potential defects within it. These tools are mounted with inspection sensors for rapid acquisition of high speed and high resolution 3D images with sub-millimeter accuracy. This high speed laser scanning is capable of pinpointing any defects due to corrosion, erosion and any geometric deformation with an accuracy that can exceed a tenth of a millimetre. Publishing inspection data directly into a synchronized and unified 3D model ensures no loss of data and enhances human interpretation while evidentially informing other co-located asset management activities as well as the entire network system.

From the use of smart pigs, smart meters to sensor webs, there is an opportunity to enable improved optimisation and efficiency of existing water infrastructure and plant. These systems will synthesise data from across the water cycle and share it across utilities, related planning and trade applications and users to inform decision making.

Ground and Surface Water

Water Atlases

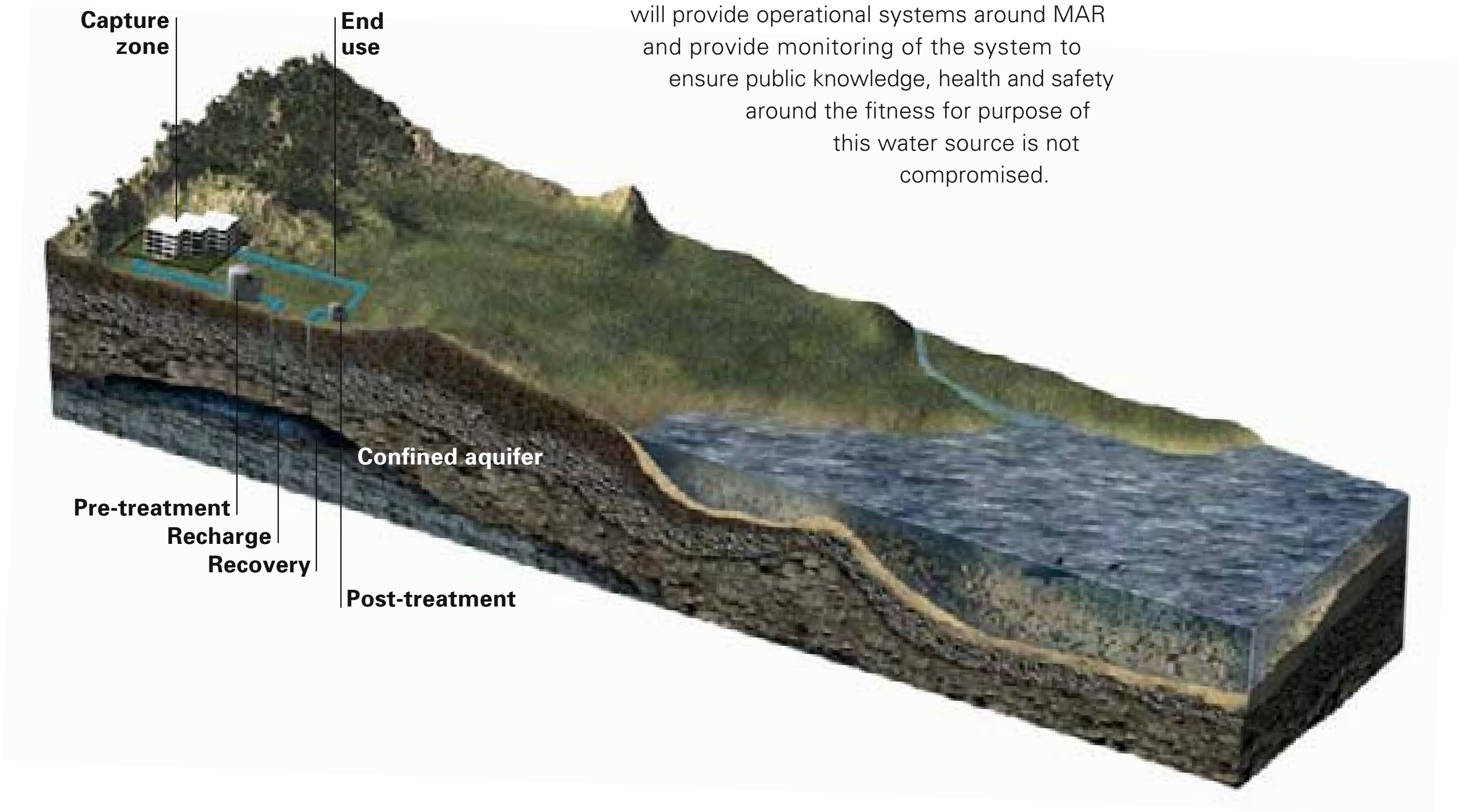
3D visualisation and smart devices can be useful in conferring and comprehending what lies below the city. A ground water atlas can help water-bore drillers, irrigators, and private householders to establish groundwater bores in the superficial aquifer at the least impact bore locations.

The data in these atlases can be updated readily with sensors and collated borehole records and information given on the state of groundwater salinity, development risk, iron staining risk and potential acid sulfate soil risk.

Water Facilitating Sustainable Communities

Water recycling will be an essential component of the total water cycle for cities of the future, providing an alternative water source with far less impact on the environment. There are many opportunities to improve water use efficiency and harvest large volumes of wastewater and stormwater that currently enter the ocean and waterways. Managed aquifer recharging (MAR) is a process whereby treated stormwater or recycled water is injected into an aquifer for later extraction.

3D visualisation will assist decision making around reuse options especially in the planning and informing the policy, planning, design and implementation decisions of MAR. Evidential 4D models informed by real-time sensor webs will provide operational systems around MAR and provide monitoring of the system to ensure public knowledge, health and safety around the fitness for purpose of this water source is not compromised.



The Visual City has capacity to provide a communal platform for the public to publish its memories and build a more meaningful understanding and respect for 'place'.

Stream Daylighting

Urban stormwater harvesting and managed aquifer recharging represent opportunities to provide a major new water sources, while helping to protect valuable waterways from excessive pollution and ecosystem degradation. Baseflows for streams can be reestablished and streams can be daylighted returning ecological, recreational and cultural-historical knowledge to communities.

CASE STUDY: *REDISCOVERY OF A FORGOTTEN STREAM*

Evaluation of water infrastructure options is not simply based on technical, environmental or cost factors. The role of public consultation informing decision making is a key part of current decision making practice. Visual City offers a collaborative platform bringing together groups and through improved accessibility to information and knowledge ensures water infrastructure outcomes best reflect this broad range of values.

The Waipapa Stream (Parnell Gully) borders one of Auckland, New Zealand, most significant open green spaces – the Domain. Prior to European settlement in Auckland, the stream was used by Maori both as a passage into the central isthmus and as a defensive 'moat'. Following settlement, Auckland's first industries were born on the Waipapa Stream - a rope maker, flour mill, shipwright, tannery, saw mill and brewery. The products produced were consumed locally and exported to Australia.

Moving forward over 100 years - the stream has been piped as part of the stormwater network. The existence and historic significance of the stream in defining the Domain and building the nation's early industries had long been erased from public memory.

Using 3D visualisation and an evidential approach for bringing together LIDAR, GPR, and precision geo-referencing of 150 year old land titles and documents, aerial imaging, cross-referencing of early photographs and paintings, the urban and natural geomorphology of the area was able to be reconstructed and comprehended. Daylighting of the Waipapa stream has been visually demonstrated to be both a technical solution to stormwater drainage in the area, and importantly, one that reinforces and restores the amenity, cultural and socio-historical values of the area.

Waipapa Stream driving a rope walk and flour mill and irrigating the first Chinese market garden in Auckland.

Historic 3D Map shows the Waipapa Stream in 1886 making its way along the Parnell edge of the Auckland Domain. The Waipapa can be seen meandering beside the railway and driving the city's first flour mill, and Rope Walk (long shed) and also irrigating the Chinese gardens that grew vegetables for the early pioneering residents. The water from the stream was used for the first baptisms and for the first brewery. 3D provides a powerful visual narrative capturing insight into social , environmental, economic and cultural life.

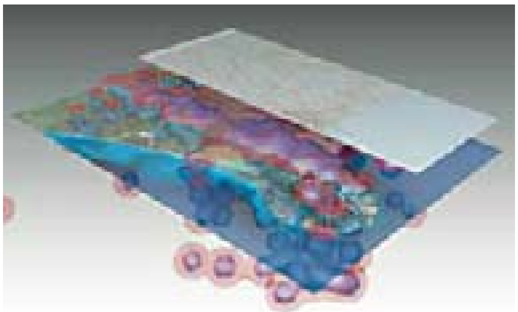
Induced seismicity

Earthquakes and tremors can be brought about by impounding water in large reservoirs and causing a depression upon the earth's crust, or by altering the hydraulic pressure head of ground water thereby changing stress patterns in the strata. Reservoir Induced Seismicity (RIS) studies, at several major dam projects around the world, provides information on the factors responsible for RIS such as geo-tectonic setting, pore-water pressure, background seismicity and reservoir water load. Any one or the combination of these factors play an important role in inducing earthquakes.

Although induced seismicity has been noted for many years and associated with a variety of causes, it is now becoming an increasingly important issue as society faces the challenges of climate change, energy production, water shortages and depletion of aquifers, proposed managed aquifer recharge and the disposal carbon dioxide through sequestration.

CASE STUDY: *IESE-NEXTSPACE CENTRE FOR ADVANCED 3D VISUALISATION (DEEP EARTH)*

The Institute of Earth Sciences and Engineering (IESE) and Nextspace have jointly established a centre for advanced visualization at the University of Auckland. Established in 2005, the IESE applies cutting edge geothermal research to commercial services in geophysical exploration, borehole seismology, ground water, reservoir monitoring, and advanced modelling. The Centre is a recognised leader in research on geo-hazards and the environment, and with 3D visualisation of vast data sets, a clearer understanding of hazards can be unveiled and communicated to further improve practices and reduce risks. Evidential data can be streamed from deep beneath the city from 1km (+)



3D visualisation of Christchurch quakes and aftershocks 2010/11 - IESE - Nextspace www.iese.co.nz

boreholes lined with multiple sensors. Residents can receive early warning of events. A greater understanding of activities associated with seismicity and its induction can avoid significant risks, evidentially drive spatial planning and design of the above ground structures.

Visualisation can be used to go back in time and can also go forward. This is a visualisation of Christchurch by Nextspace suggesting the post-earthquake future.
Created for The Sunday Star-Times and published on March 13 2011

Storm and Sewer Systems

Optimising peak and non peak demands

Wastewater systems which comprise sewer network and wastewater treatment plants are subject to large fluctuations in flow and concentrations. During storm water situations large amounts of pollutants are diverted untreated to the receiving waters when the system breaches its designed peak capacity. 3D visualisation of the wastewater systems together with smart systems can optimise across the network the management of peak capacity and corresponding spare capacity in non-peak times. There is tremendous scope for 3D visualisation tools with dynamic evidential models fed by real-time telemetry. The potential pay back is enormous both in economic and environmental terms.

CCTV: Blockage detection and resolution tool

From CCTV data, it is possible to visualise the inside of the pipe and 'walk thru' identifying where the block exists. By querying the block for composition, together with other information associated with the wastewater system such as property types and discharges, known trade waste discharges, trees at the location, the factors responsible for the blockage will be able to be diagnosed. The rendered visualisation of the pipe and CCTV could be archived for facility management of asset lifecycle (or legal requirements). CCTV data streamed into the 3D model and visualised concurrently informs compliance inspection and engineers as they appraise the state of networks prior to a heavy storm.

Recent advances in hyperspectral imaging may soon be incorporated into the next generation of CCTV cameras. In addition to identifying choke points, this technology will also distinguish details of the material type – such as grease and fat – and inform evidence for cases where there may be opportunity for preventative action.

Tree Roots

In some areas, unintended consequences of urban environmental initiatives (such as treescape or greening programmes) impact service delivery. In addition to tree planting on public land, much of the choking can be traced back to the root systems of trees planted on private land. While there are clearly important merits for the greening of cities there is a huge and often largely avoidable cost associated with tree management programmes. These costs may reach into the millions for larger cities.

Utilising a 3D visualisation and a smart devices (such as an iPad) data on tree root risks can be identified for avoidance or inform meaningful discussion with home owners. Tree sizes can be updated with LIDAR data sweeps, and hyperspectral imaging used in the automated identification of tree species from leaf absorption profiles.

Salt Water

Pacific Island

Small island countries are among the most vulnerable to future sea level rise and climate change. Inundation and flooding are the common threats to these islands because of their low-lying setting; the problem is exacerbated by the social trends of population growth and migration to main islands, in particular to the capital cities. Other threats include beach erosion, saltwater intrusion, ground water contamination and impacts on the infrastructure and coastal society. For the island countries, the response to sea level rise and climate change focuses there is an urgent need for visualisation of evidential data. This can assist in informing and monitoring the adaptation to new practices and visual articulation of the issues to local and international concerns.

Developing the Visual City capabilities in Water

Integrated urban water management relies on trusted evidential data, formed into models. Simulation can be used to generate understanding and prediction of the behaviour of the individual urban water cycle components and their interactions.

As the Belgrave case study highlights, data visualisation unimpeded by conventions of dimension and cartography, means it is possible to grasp the entirety of relations among the various components of the urban water cycle and so develop a holistic approach to solving urban water problems. The study demonstrates how informative 3D visualisations give us a NEW method of engagement with stakeholders.

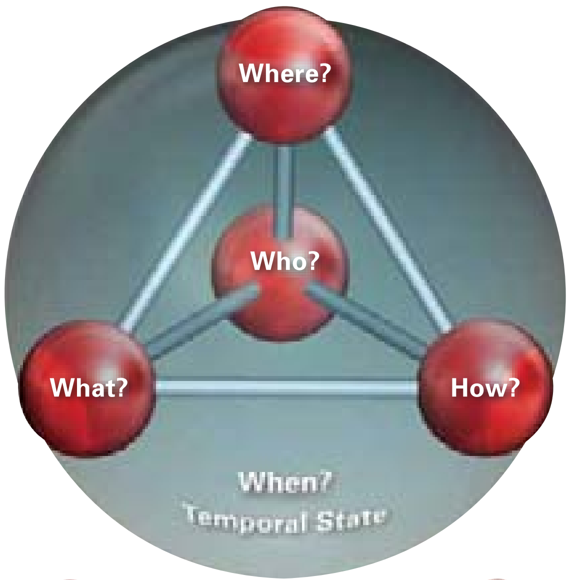
WHERE – is a reference to the spatial or terrestrial point of interest. Assets, People, Risks, Knowledge, and Events can all be associated with ‘where’. Where is multi-dimensional space and serves as the primary reference index. The blurring of the physical and digital worlds begins at where.

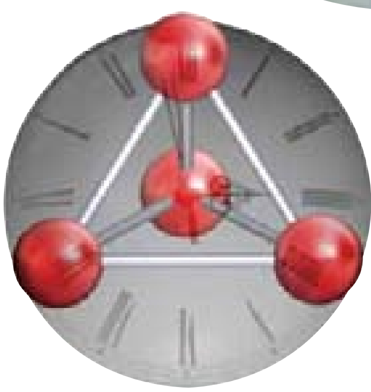
WHAT – describes the ‘thing’ – usually an object such as a pipe, valve, manhole, acquifer, tree.

WHO – is the human factor, refering to a person, their status or alternatively their competencies and qualifications for the task at hand.

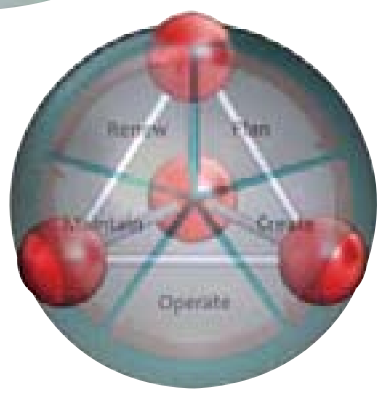
HOW – is the learning know-how and can include several types of evaluation and assessment. Learning may be technical, regulatory, or informative – accessible as Just-In-Time (JIT), or a prerequisited requirement for a specific task. Assessment can be observational, formative, or qualification (high stakes). This know-how knowledge is semantically mapped to the 3D objects (What) and places (Where).

WHEN – is the dimension of temporal (time) journey and also defines the state of the object (What), place (Where) and person (Who). An object at any time may be in one of a number of states. Its state will have impact upon the actions applied to the object.



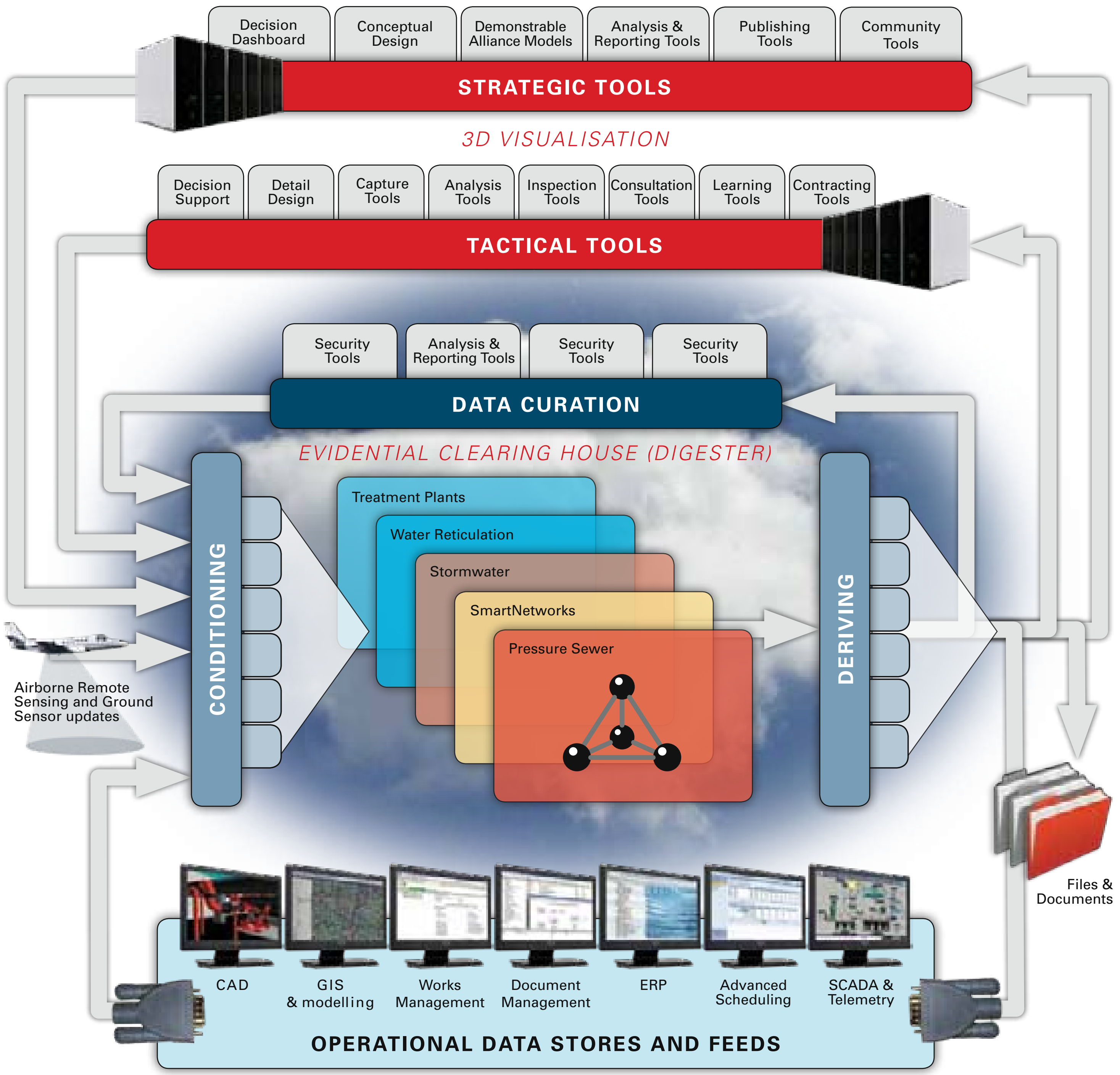


Time continuum



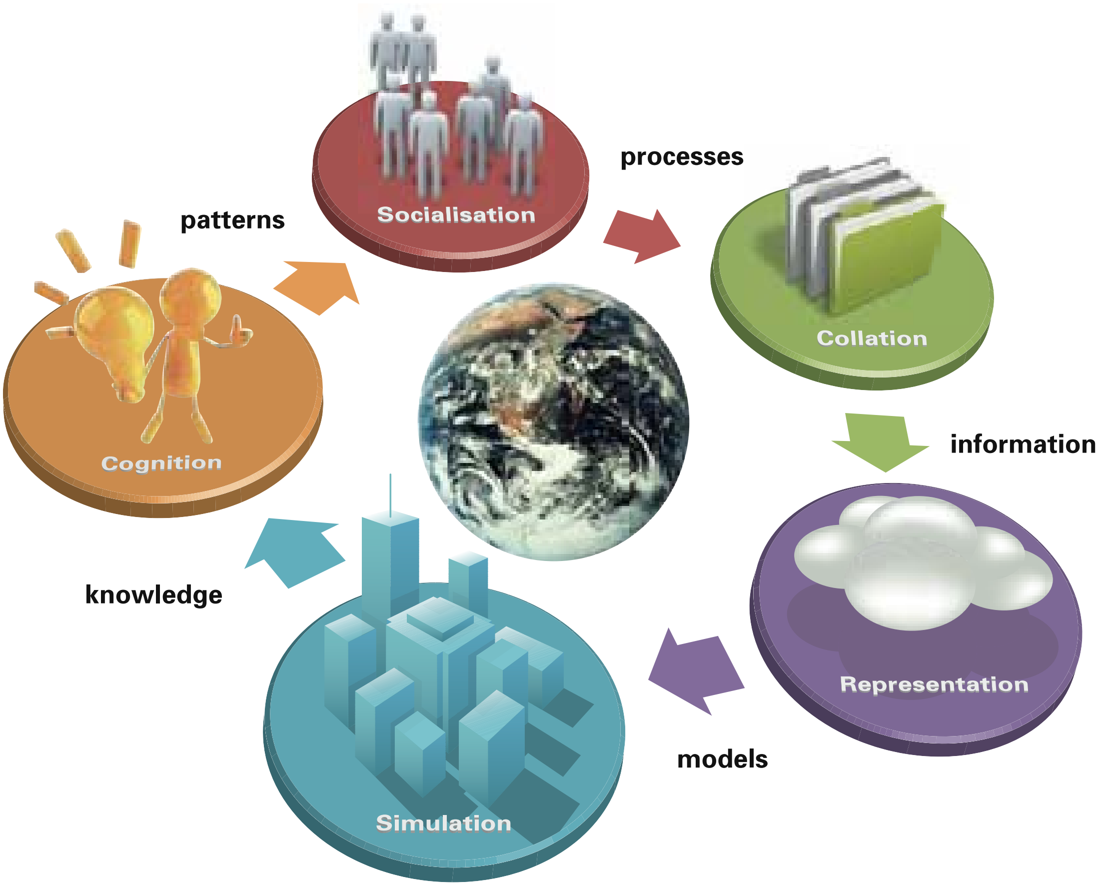
Punctuated states

Extending this to the effective management of the entire urban water requires understanding the impact of human activity on both the urban hydrological cycle – including its processes and interactions – and the environment itself - each measured across a range of attributes: temporal, spatial, tactical, strategic. As increasing amounts of this data becomes accessible, more sophisticated evidential-based methods of management to deal with pre-conditioning, 'digestion' and derived new data outcomes as increasingly more complex fusion processes become available. A range of strategic and tactical tools visualise data across a range of decision making levels – strategic and tactical – both informing existing operational, management and strategic capabilities of the water utility.



Creating a common language through visualisation

Visualisation has been demonstrated to be a key in bringing together seemingly disparate knowledge and information that is related through space or place. The Visual City is based on the development of a 'visual language' that can articulate meaningful and cohesive answers to the questions: "How are we doing?", "Where are we going?", and "What is next?". The visual language is one of progression of our society into the future.



SOCIALISATION – the liberation of knowledge from patterns to people in the pursuit of decision making, socio-political capital, championship, accountability, consultation, market receptivity, bridging organisations, education, and stimulation.

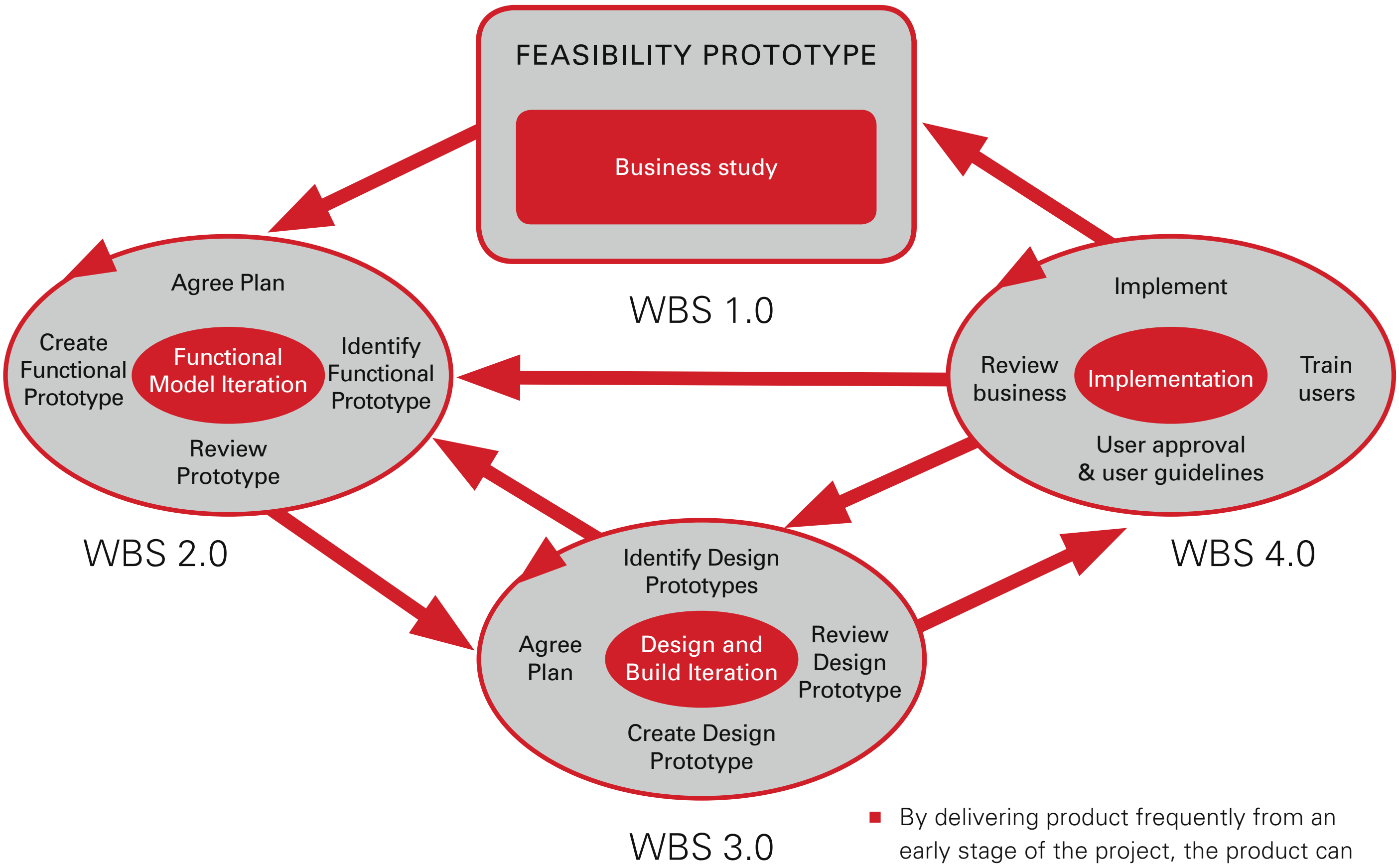
COLLATION – the harvesting of data from processes such as remote sensing, operations, exchanges, surveys, live data feeds, online services, archives, and crowd sourcing.

REPRESENTATION – the process of spatially, temporally, semantically indexing information; and evidentially translating, conditioning, and configuring it into a synchronised unified multi-dimensional model.

SIMULATION – mapping 3d models to the 4d dynamics of reality and extracting knowledge by changing variables or states of the system.

COGNITION – the synthesis of knowledge into patterns that can be prescribed into the socialisation contexts. Recent breakthroughs in Artificial Intelligence (AI) are enabling the development of algorithms based upon Bayesian networks that can utilise and learn from existing data. This can significantly assist in the driving socialisation processes to establish Visual Cities with a language of progression.

Developing Water in the Visual City prototypes & tools



The solution is developed from the initial feasibility prototype through an evolutionary process based on an agile methodology.

The proposed rapid prototype approach will focus on frequent delivery of product, with assumption that to deliver something "good enough" earlier is always better than to deliver everything "perfectly" in the end.

The development is iterative and incremental and driven by users' feedback to converge on an effective planning solution. The rationale for this approach is based upon the following:

- By delivering product frequently from an early stage of the project, the product can be tested and refined in iterative cycles.
- The main criterion for acceptance of a "deliverable" is delivering a system that addresses the current planning needs. Delivering a perfect system which addresses all possible business needs is less important than focusing on critical functionalities.
- The high level scope and requirements should be base-lined before the project starts.
- Communication and cooperation among all project stakeholders is required to be efficient and effective.

Nextspace was established as a partnership between Right Hemisphere and the New Zealand Government to catalyse multi-dimensional visualisation in business and government and enable New Zealand to take a leading role in the new wave of technological innovation.

Nextspace provides 3D visualisation solutions for businesses. We help organisations with complex products or infrastructures manage their business processes visually to collaborate, communicate and train more efficiently.

Our solutions amalgamate rich multi-dimensional data from corporate and external databases creating powerful productivity and decision-making tools. The result is core business processes that are more efficient, accurate and engaging.

We deliver our solutions with partners, including world-leading visual enterprise provider Right Hemisphere whose success in the global aerospace industry we leverage to solve business problems in other industries.

www.nextspace.co.nz

South East Water Limited provide water and sewerage services to nearly 600,000 residential, industrial and commercial properties in an area covering 3,640 square kilometres in the eastern part of Melbourne, Australia. South East Water manages infrastructure and assets with a net book value in excess of $1.3 billion and is responsible for 8336KM of water mains, 7724KM of sewer pipes, 78 water pump stations, 237 sewer pump stations and 9 sewer treatment plants that serve 1.3M people.

One of three key Melbourne water retailers, South East Water Limited has maintained and updated its Geographic Information System (GIS) system over many years. The GIS system is fundamental to the company's day to day operations, supporting asset management and customer service activities across the business. South East Water's system is ranked highly for its quality and integrity, traditionally providing information in 2 dimensions via a suite of applications, tools, products and customised developments, designed to meet the company's growing needs. In recent times South East Water has been exploring opportunities to represent key infrastructure and asset management information in 3D, leading to the establishment of an association with Nextspace.

In mid to late 2009 South East Water started to explore the potential for 3D visualisation and modelling and its application across the Water Industry. A key objective for Nextspace is to develop a three dimensional 'visual city' that would allow numerous businesses, government organisations, councils and utilities to draw on data from a centralised source, using it to generate 3D visualisations. Between South East Water and Nextspace an opportunity was identified to 'pilot' 3D visualisation technology in support of communication and vital decision making processes as part of the Belgrave Heights Pressure Sewer Project.

www.southeastwater.com.au

'us' - Utility Services is a strategic alliance between: South East Water and a consortium of Thiess Services and Siemens Limited.

These three organisations combine their network of capabilities, know how and innovative skills - to deliver exceptional operation, maintenance and construction services to South East Water's infrastructure.

This unique mix makes it also possible to share their competencies, technologies and innovative solutions with other utilities, councils and industrial customers.

www.usus.com.au

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Notes

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